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THE OIL HEATING ASSOCIATION OF CANADA CLEAN AIR PROGRAM PHASE II: EVALUATION OF BURNERS WITH HIGH-SPEED MOTORS IN WARM-AIR FURNACES

by

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THE OIL HEATING ASSOCIATION OF CANADA CLEAN-AIR PROGRAM

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ABSTRACT

This report contains the primary data and evaluation of the tests carried out on the "Grimsby" and "Anthes" warm-air furnace on two burners only. These burners, the Beckett Model AF and the Aero Model F-AFC were tested with 3450-rpm motors and were operated with and without slip clutches.

RESUME

Ce rapport contient les données premières et l'évalation des essais qu'on a mis à l'exécution sur les fourneaux d'air chaud de "Grimsby" et "Anthes" avec deux brûleurs seulement. On a éprouvé ces brûleurs, le Beckett modèle AF et l'Aero modèl F-AFC avec les moteurs de 3450 rpm, avec et sans des embrayages coulants.

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* Prepared for the Equipment and Service Committee of the Oil Heating Association of Canada: Chairman, C. S. James.

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INTRODUCTION

Details of the test equipment and experimental procedures to be used in the OHA Clean Air Program has been described in Mines Branch Investigation Report IR 73-32 entitled: Phase I: Facilities, Techniques, and Procedures. In Phase II of the program performance tests were done with both warm-air furnaces using the two burners that were equipped with high-speed 3450-rpm motors. The results are given in Appendix A. The discussion is presented in the same order as the data tabulated in Appendix A.

DISCUSSION OF RESULTS: STEADY-RUNNING COMBUSTION PERFORMANCE

Combustion Performance at the Standard Draft Condition

The test procedure required that the burners were adjusted to a zero smoke number at a "standard" draft condition of minus 0.02 inch water gauge (wg). The only test conditions at which a CO_2 level greater than 9% was not achieved a at this standard condition were at firing rates of 0.5 US gph. These test conditions are listed in Table 1.

TABLE 1

Test Conditions Leading to High-Excess-Air Combustion
(CO_2 < 9.0%)

Burner	Furnace	Firing Rate	(CO_2 Level (at standard draft) NSC	SC
Beckett	Grimsby	0.5	6.3%	7.2%
Aero	Grimsby	0.5	1/	7.8%
	Anthes	0.5	6.5%	6.5%

1/ In tests without a slip clutch the Aero Burner (0.5 US gph) in the Grimsby furnace performed satisfactorily (CO_2 = 10.5%).

NSC: No slip clutch.
SC: Slip Clutch

A statistical comparison of the slip clutch and the no-slip clutch performances of the burners indicated that the differences were not significant at the 95% probability level.

A statistical comparison of the Grimsby/Anthes furnace performance of the burners indicated that the differences were not significant at the 95% probability level.

(1) The steady-state combustion performance of the test burners under standard conditions is practically the same in both test furnaces.

(2) The steady-state combustion performance of the test burners under standard conditions is not significantly changed by the incorporation of a slip clutch.

(3) The only test conditions where a satisfactory (low) excess-air level could not be achieved (CO_2 > 9%) occured at the minimum firing rate.

Combustion Performance Under Modified Draft Conditions

The modified-draft conditions were obtained by altering the setting of the barometric chimney damper without changing the burner. The results therefore reflect differences in performance that could be expected under the influence of external wind conditions.

The modified-draft condition of minus 0.07 inch wg could always be achieved with all combinations of furnace and burner and firing rate. Increasing the draft to minus 0.07 inch wg did not produce an increase in smoke level or carbon monoxide emission in any of the test combinations. The general effect was to increase the excess-air level.

The modified draft condition of plus .05 inch wg could not always be achieved on the Anthes furnace except at the expense of excessive smoke production and an increase in the carbon monoxide content of the flue gases. These emissions were associated with a decrease in the excess-air level.

The changes in excess-air level due to changes in the draft condition has been calculated as a percentage change in mass flow through the burner per 0.01-inch wg change in chimney draft to characterize the stability of the burner and furnace combinations.

TABLE 2

The Effect of Chimney Draft on Burner Air Flow Rate

Furnace	Burner	Nominal Firing Rate	% Change in Mass Flow per 0.01 inch wg Change in Chimney Draft			
			Standard to minus 0.07 inch wg		Standard to plus 0.05 inch wg	
			A	B	A	B
Grimsby	Beckett	0.5	7.1	4.7	0.9	3.1
		0.75	0.6	1.6	2.1	2.1
		1.00	1.2	1.5	1.3	0.5
	Aero	0.5	2.1	3.7	1.5	2.2
		0.75	2.2	4.0	2.9	2.9
		1.00	2.1	2.1	1.5	1.6
Anthes	Beckett	0.5	5.6	8.4	1.1	1.0
		0.75	1.8	1.0	7.4	6.4
		1.00	1.8	1.8	4.3	4.3
	Aero	0.5	7.0	10.1	5.2	5.6
		0.75	7.2	8.5	8.2	6.6
		1.00	5.4	5.1	0.6	0.7

A: Tests without slip clutch.

B: Tests with slip clutch.

It is apparent that very remarkable changes in mass flow occur when either burner is fired in the Anthes furnace; indeed only one test combination in the Grimsby furnace indicated that large changes in mass flow were caused by changes in chimney draft.

The reason for the susceptibility of the Anthes furnace to changes in chimney draft lies in the design of the furnace. The design is such that a considerable proportion of the combustion air is inspirated into the chamber around the burner blast tube. The air flow through the burner does not change greatly under the influence of the changed chimney draft but the quantity of inspirated air may change considerably. The net result is that a burner which operates at 20 per cent excess-air under the minus 0.02 inch wg "standard" draft condition can go to either near or sub-stoichiometric condition when the chimney draft is reduced to below plus 0.02 inch wg. This performance is inherent in the furnace design and a similar performance can be expected from other units incorporating ceramic fibre combustion chambers unless the inspiration of combustion air around the blast tube is designed out of the system.

Carbon Monoxide Production under Modified Draft Conditions

At the standard draft condition (minus 0.02 inch wg) only two test combinations produced a carbon monoxide concentration greater than 20 ppm. (Grimsby, Beckett, 0.5 US gph, and Anthes, Aero, 1.00 US gph).

At the increased draft condition (minus 0.07 inch wg) only one test combination produced a carbon monoxide concentration greater than 20 ppm (Grimsby. Beckett, 0.5 US gph).

At the reduced draft condition (plus 0.05 inch wg) several test combinations produced a carbon monoxide concentration greater than 20 ppm.

Grimsby:	Beckett	at	0.5 and 1.00 US gph
Anthes:	Beckett	at	0.5 and 0.75 US gph
Anthes:	Aero	at	0.75 and 1.00 US gph

The biggest change occured with the Aero burner in the Anthes furnace firing at 0.75 US gph, when a steady-state carbon monoxide concentration of 0.25% was recorded. Significantly this is the test combination at which the biggest change in mass flow due to the changed chimney draft was observed.

Smoke Production under Modified Draft Conditions

At the standard draft condition (minus 0.02 inch wg) all test combinations were capable of operating with a smoke number of 1 or less.

At the increased draft condition (minus 0.07 inch wg) only one test combination showed an increase in smoke numbers. (Grimsby, Aero, 0.75 US gph). The change was from a smoke number of 0 to a smoke number in the range of 0 to 1. This change is not significant.

At the reduced draft condition plus .05 inch wg, all test combinations showed an increase in smoke numbers. In the Grimsby furnace, the increase was to a maximum smoke number of 6; in the Anthes furnace the increase was to maximum smoke number of 9. This again reflects the generally larger changes in burner mass flow rate that were observed in the Anthes furnace.

Nitric Oxide Emissions

Grimsby Furnace

The nitric oxide emission - expressed as lb/1000 lb fuel - did not vary greatly with firing rate of either burner. The general level was higher with the Beckett burner.

There did not appear to be any major change in nitric oxide emission that could be attributed to the change in draft conditions.

Anthes Furnace

The nitric oxide emission - expressed as lb/1000 lb fuel - increased with increased firing rate for both burners. The general level was higher with the Aero burner. The highest nitric oxide emission was generally recorded at the highest draft condition (highest excess-air level) irrespective of burner or firing rate.

A statistical comparison of the nitric oxide emissions from the Grimsby and Anthes furnaces under identical test conditions indicated that the increased emission from the Anthes furnace was significant at the 95% probability level.

Flue Gas Losses

In all cases, the flue gas loss increases as the furnace draft increases, i.e., as the excess-air level increases.

DISCUSSION OF RESULTS: START-UP AND SHUT-DOWN COMBUSTION PERFORMANCE

During the early tests on these two burners, means to continuously meter smoke was not available in the laboratory. The smoke numbers reported are those measured by Bacharach smoke meter on a sample started at either shut-down or start-up.

Performance without Slip Clutch: Start-Up Smoke

In the Grimsby furnace, both burners at all firing rates gave start-up smoke numbers in the range 4 to 6 under the standard draft condition without evidence of unburnt fuel in the smoke spot. The single exception to this (Beckett, 0.5 US gph) showed a smoke number of 2 and considerable yellow staining.

Under modified draft conditions, the start-up smoke number increased as the draft decreased and smoke numbers of 7 to 8 were recorded under the lowest draft condition (plus 0.05 inch wg).

In the Anthes furnace there was a marked difference between the performance of the two burners. The Aero burner gave start-up smoke numbers in the range 8 to 9 under all draft conditions whereas the Beckett burner gave a similar performance to that observed in the Grimsby furnace; i.e., smoke number 2 to 5 at the standard draft and increasing from 7 to 9 as the draft decreased.

Performance without Slip Clutch: Start-Up Carbon Monoxide

Peak carbon monoxide concentrations in excess of the steady running concentration were observed during the start-up cycle of all burners in both furnaces.

With a single exception (the Beckett burner in the Grimsby furnace at a firing rate of 0.5 US gph), the general trend was to give peak concentrations between 200 and 500 ppm at the standard draft condition; this peak concentration increased as the chimney draft decreased.

The exceptional test combination referred to gave peak concentrations of 900 ppm at the standard draft condition; this increased to 2600 ppm at the decreased draft condition and increased to more than 1% at the increased draft condition. These extremely high transient concentrations were associated with evidence of unburnt fuel on the smoke stains.

Performance without Slip Clutch: Shut-Down Smoke

The smoke levels generated on shut-down at the standard draft condition were between 4 and 9 in the Grimsby furnace and between 5 and 9 in the Anthes furnace.

It appears that decreasing the furnace draft increases the measured smoke number on shut-down. In 9 of the 12 burner/firing rate combinations tested, the maximum shut-down smoke number occured at the lowest chimney draft condition.

The Beckett burner performed better in the Grimsby furnace on shut-down, whereas the Aero burner performed better in the Anthes furnace.

Performance without Slip Clutch: Shut-Down Carbon Monoxide

Peak carbon monoxide concentrations between 200 and 800 ppm were measured on shut-down. There did not appear to be any relationship between test conditions and peak carbon monoxide concentration on shut-down.

Performance with Slip Clutch: Start-Up Smoke

The use of a slip clutch reduced the smoke number on start-up for 23 of the 36 test combinations; the smoke number increased in 8 test combinations and remained unchanged in 5 test combinations.

Performance with Slip Clutch: Start-Up Carbon Monoxide

The use of a slip clutch eliminated the carbon monoxide peak on start-up in 32 of the 36 test combinations. In 3 of the remaining 4 combinations, the peak carbon monoxide concentration was greatly reduced and in one test combination only. The peak carbon monoxide concentration remained unchanged.

Performance with Slip Clutch: Shut-Down Smoke

The presence of a slip clutch reduced smoke number in 30 of the 36 test conditions compared to that measured without a slip clutch. The maximum smoke number was measured at the lowest draft condition as was the case in tests without a slip clutch.

Performance with Slip Clutch: Shut-Down Carbon Monoxide

The presence of a slip clutch eliminated the formation of carbon monoxide in all of the test conditions.

DISCUSSION OF RESULTS: NOISE LEVELS

The noise levels (dBA) and frequency distribution from both burners were not significantly affected by either furnace, or firing rate, or draft.

The Beckett burner is less noisy (dBA) than the Aero burner under all test conditions.

SUMMARY

1. The steady running combustion performance of either test burner was not significantly different in the two test furnaces at the standard draft condition. Under modified draft conditions, the combustion performance deteriorated most markedly in the Anthes furnace. This appeared to be a consequence of the furnace design.

2. The steady running performance of the test burners was not significantly changed by the incorporation of a slip clutch.

3. The only test combinations where a satisfactory excess-air level ($CO_2 > 9\%$) could not be achieved at the standard draft condition occurred at the minimum firing rate for both burners.

4. When either burner was fired in the Anthes furnace, the nitric oxide emission was significantly greater than the emission from the same burner in the Grimsby furnace.

5. The use of a slip clutch significantly improved the performance of both burners during start-up and shut-down cycles. The improvement was most marked during shut-down when transient peaks of carbon monoxide were eliminated and transient smoke numbers of zero were recorded in thirty of the thirty-six test combinations.

6. The Beckett burner was less noisy than the Aero burner under all test conditions.

REFERENCES

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2. Henderson, C. Special Projects Co-ordinator, Gulf Oil Canada. Private Communication.

3. CSA Standard 140.4. 1972 "Oil-Fired Warm Air Furnaces".

4. CSA Standard 140.0. 1972 "General Requirements for Oil Burning Equipment"

APPENDIX A: TABULATION OF TEST DATA

TABLE A1

STEADY-RUNNING PERFORMANCE

Combustion Conditions: Grimsby Furnace - No Slip Clutch

Burner	Nozzle US gph	Draft Inch wg	CO_2 %	O_2 %	CO ppm	C_xH_y ppm	Smoke Number
Beckett	0.5	+ 0.05	7.0	9.9	100	< 6	3 1/
		- 0.02	6.3	10.6	80	< 6	0 1/
		- 0.07	5.1	11.7	80	< 6	0
Beckett	0.75	+ 0.06	11.8	3.6	< 20	< 6	0/1
		- 0.02	10.2	4.8	< 20	< 6	0
		- 0.06	9.9	6.5	< 20	< 6	0
Beckett	1.00	+ 0.075	11.7	3.8	100	< 6	1
		- 0.02	10.8	5.4	< 20	< 6	0/1
		- 0.08	9.6	7.0	< 20	< 6	0
Aero	0.5	+ 0.06	11.7	4.9	< 20	< 6	2/3
		- 0.02	10.5	6.8	< 20	< 6	0/1
		- 0.07	9.2	7.8	< 20	< 6	0
Aero	0.75	+ 0.015	11.2	5.0	< 20	-	4/5
		- 0.02	10.6	5.4	< 20	-	0
		- 0.07	9.0	7.3	< 20	-	0/1
Aero	1.00	+ 0.06	11.7	4.9	< 20	< 6	2/3
		- 0.02	10.5	6.8	< 20	< 6	0/1
		- 0.07	9.2	7.8	< 20	< 6	0

1/ The system pulsated on ignition; the pulsations died slowly taking about three minutes to disappear.

TABLE A2

STEADY-RUNNING PERFORMANCE

Combustion Conditions: Anthes Furnace - No-Slip Clutch

Burner	Nozzle US gph	Draft Inch wg	CO_2 %	O_2 %	CO ppm	C_xH_y ppm	Smoke Number
Beckett	0.5	+ 0.03	10.1	5.7	200	-	4
		- 0.015	9.5	6.2	< 20	-	1
		- 0.04	8.3	7.3	< 20	-	1
"	0.75	+ 0.02	13.0	1.9	200	-	5
		- 0.02	9.0	7.9	< 20	< 6	0
		- 0.07	8.2	8.1	< 20	< 6	0
"	1.00	+ 0.04	13.6	2.0	20	< 6	7/8
		- 0.02	10.7	6.4	0	< 6	0
		- 0.08	8.9	7.9	< 20	< 6	0
Aero	0.5	+ .05	10.8	4.9	< 20	-	3
		- 0.02	6.5	10.8	< 20	-	0
		- 0.05	5.6	11.8	< 20	-	0
"	0.75	+ 0.02	14.0	0??	2500	-	9
		- 0.015	9.7	5.4	< 20	-	0
		- 0.07	7.2	9.0	< 20	-	0
"	1.00	+ .03	10.8	8.2	66	< 6	9
		- 0.025	9.9	6.5	70	< 6	0
		- 0.055	8.5	7.9	50	< 6	0

TABLE A3

STEADY-RUNNING PERFORMANCE

Combustion Conditions: Grimsby Furnace - Slip Clutch

Burner	Nozzle US gph	Draft Inch wg	CO_2 %	O_2 %	CO ppm	C_xH_y ppm	Smoke Number
Beckett	0.5	+ 0.05	8.8	8.0	< 20	< 6	3
		- 0.02	7.2	9.0	< 20	< 6	1
		- 0.05	6.4	10.8	0	< 6	0/1
Beckett	0.75	+ 0.05	12.2	3.7	< 20	< 6	5/6
		- 0.02	10.8	5.0	0	< 6	1
		- 0.065	9.6	5.9	0	< 6	0/1
Beckett	1.00	+ 0.065	10.9	4.6	0	< 6	1
		- 0.02	10.4	5.0	0	< 6	0
		- 0.07	9.6	5.4	0	< 6	0
Aero	0.5	+ 0.02	8.7	7.3	0	-	3
		- 0.025	7.8	8.4	0	-	0
		- 0.04	7.4	8.5	0	-	0
Aero	0.75	+ 0.01	11.0	4.6	0	< 6	4/5
		- 0.02	10.7	5.4	< 20	-	0
		- 0.05	8.8	7.4	0	-	0/1
Aero	1.00	+ 0.06	11.8	4.8	< 20	< 6	2/3
		- 0.02	10.5	6.8	< 20	< 6	0/1
		- 0.07	9.2	7.8	-	< 6	0

TABLE A4

STEADY-RUNNING PERFORMANCE

Combustion Conditions: Anthes Furnace - Slip Clutch

Burner	Nozzle US gph	Draft Inch wg	CO_2 %	O_2 %	CO ppm	C_xH_y ppm	Smoke Number
Beckett 3450 -rpm Motor	0.5	+ 0.025	8.8	7.0	-	< 6	7/8
		- 0.015	9.4	6.2	-	< 6	4
		- 0.03	8.3	7.3	-	< 6	1
Beckett	0.75	+ 0.03	13.45	2.1	200	< 6	4
		- 0.02	9.0	7.8	< 20	< 6	0
		- 0.06	8.6	7.7	< 20	< 6	0
Beckett	1.00	+ 0.04	13.6	2.0	20	< 6	7/8
		- 0.02	10.7	6.4	0	< 6	0
		- 0.08	8.9	7.9	0	< 6	0
Aero	0.5	+ 0.045	10.8	4.9	0	0	0
		- 0.02	6.5	10.8	0	0	0
		- 0.04	5.6	11.8	0	0	0
Aero	0.75	+ 0.02*	14.0	1.0	2500	-	9
		- 0.15	9.9	5.4	0	-	0
		- 0.07	7.1	9.1	0	-	0
Aero	1.00	+ 0.03	10.8	8.2	66	12	9
		- 0.02	9.9	6.5	20	< 6	0
		- 0.08	7.5	8.3	< 20	< 6	0

*Test Incomplete: Excessive smoke formation.

TABLE A5

STEADY-RUNNING PERFORMANCE

Flue Gas Losses: Grimsby Furnace

Burner	Firing Rate	Nominal Draft Inch wg	Flue Gas	
			Flue Gas Loss %	Temperature °F
Beckett		-.02	15.7	290
3450 rpm motor	0.5	-.07	17.0	305
		+.05	13.5	310
		-.02	13.7	335
Beckett	0.75	-.07	15.2	340
		+.05	12.8	355
		-.02	16.4	425
Beckett	1.00	-.07	18.5	460
		+.05	15.9	467
Aero		-.02	14.8	300
3450 rpm motor	0.5	-.07	15.7	300
		+.05	14.0	310
		-.02	12.4	260
Aero	0.75	-.07	13.4	290
		+.05	11.4	280
		-.02	15.4	382
Aero	1.00	-.07	17.5	395
		+.05	14.2	410

TABLE A6

STEADY-RUNNING PERFORMANCE

Flue Gas Losses: Anthes Furnace

Burner	Firing Rate	Nominal Draft Inch wg	Flue Gas	
			Flue Gas Loss %	Temperature °F
Beckett	0.5	-.02	13.6	370
		-.07	14.6	360
		+.05	16.2	306
Beckett	0.75	-.02	18.6	438
		-.07	20.3	455
		+.05	14.6	482
Beckett	1.00	-.02	18.6	460
		-.07	21.3	515
		+.05	15.1	550
Aero	0.5	-.02	20.8	305
		-.07	24.1	400
		+.05	12.7	420
Aero	0.75	-.02	18.2	300
		-.07	22.3	472
		+.05	11.2	470
Aero	1.00	-.02	19.4	400
		-.07	24.5	510
		+.05	15.4	540

TABLE A7

STEADY-RUNNING PERFORMANCE

Nitric Oxide Emissions: Grimsby Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	Nitric Oxide Emission			
			A		B	
			ppm	lb/1000 lb fuel	ppm	lb/1000 lb fuel
Beckett 3450 -rpm Motor	0.5	+ 0.05	65	1.72	80	2.11
		- 0.02	71	2.24	85	2.71
		- 0.07	59	2.09	74	2.59
	0.75	+ 0.05	89	1.75	101	1.98
		- 0.02	91	1.99	106	2.31
		- 0.07	85	2 10	90	2.23
	1.00	+ 0.05	85	1.89	89	1.99
		- 0.02	76	1.73	93	2.11
		- 0.07	86	2.09	85	2.07
Aero 3450-rpm Motor	0.5	+ 0.05	89	1.77	95	2.35
		- 0.02	80	1.75	70	2.05
		- 0.07	78	1.94	70	2.11
	0.75	+ 0.05	70	1.46	71	1.54
		- 0.02	74	1.60	82	1.84
		- 0.07	74	1.88	80	2.12
	1.00	+ 0.05	89	1.76	89	1.81
		- 0.02	82	1.79	83	1.87
		- 0.07	80	1.81	76	1.99

A - Tests without slip clutch.

B - Tests with slip clutch.

TABLE A8

STEADY-RUNNING PERFORMANCE

Nitric Oxide Emissions - Anthes Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	Nitric Oxide Emission			
			A		B	
			ppm	lb/1000 lb fuel	ppm	lb/1000 lb fuel
Beckett	0.5	+ 0.05	85	1.99	81	2.13
		- 0.02	90	2.21	76	1.89
		- 0.07	77	2.15	75	2.08
	0.75	+ 0.05	100	1.86	85	1.50
		- 0.02	87	2.25	89	2.25
		- 0.07	85	2.39	82	2.20
	1.00	+ 0.05	125	2.18	121	2.19
		- 0.02	118	2.67	123	2.72
		- 0.07	104	2.71	120	3.07
Aero 3450 - rpm Motor	0.5	+ 0.05	85	1.99	104	2.34
		- 0.02	69	2.57	84	2.96
		- 0.07	59	2.19	-	-
	0.75	+ 0.05	99	2.27	-	-
		- 0.02	97	2.23	132	3.09
		- 0.07	76	2.44	102	3.27
	1.00	+ 0.05	93	2.92	133	3.11
		- 0.02	100	2.35	127	3.02
		- 0.07	120	3.33	115	3.50

A - Tests without slip clutch.

B - Tests with slip clutch.

TABLE A9

START-UP AND SHUT-DOWN PERFORMANCE

Start-Up: Grimsby Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	No Slip Clutch		Slip Clutch	
			Smoke Number	Peak CO %	Smoke Number	Peak CO
Beckett 3450-rpm Motor	0.05	+ 0.05	yellow [1]	0.26	4	0
		- 0.02	2	0.09	4	0
		- 0.07	2/3 [1]	> 1	4	.05%
Beckett	0.75	+ 0.05	7	0.02	7/8	.005
		- 0.02	5/6	0.02	4/5	0
		- 0.07	3/4	0.015	3/4	0
Beckett	1.00	+ 0.05	8	-	2	0
		- 0.02	6	0.02	2	0
		- 0.07	3/4	0.02	1	0
Aero 3450-rpm Motor	0.05	+ 0 05	7	-	3	0
		- 0.02	5	-	1	0
		- 0.07	5	-	1	0
Aero	0.75	+ 0.05	8	-	5	0
		- 0.02	5	-	3	0
		-.0.07	5	-	4	0
Aero	1.00	+ 0.05	7	-	2/3	.135%
		- 0.02	4	-	2	0
		- 0.07	6	-	2	0

[1] Evidence of unburnt fuel.

TABLE A10

START-UP AND SHUT-DOWN PERFORMANCE

Shut-Down: Grimsby Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	No Slip Clutch Smoke Number	No Slip Clutch Peak CO%	Slip Clutch Smoke Number	Slip Clutch Peak CO %
Beckett 3450 -rpm Motor	0.5	+ 0.05	2	-		
		- 0.02	5	-		
		- 0.07	1	-	2/3	0
	0.75	+ 0.05	9	0.03	7	0
		- 0.02	9	0.03	4/5	0
		- 0.07	8	0.02	2	0
	1.00	+ 0.05	9	0.025		
		- 0.02	8	0.02		
		- 0.07	7	-		
Aero 3450 -rpm Motor	0.5	+ 0.05	5		1	0
		- 0.02	4		1	0
		- 0.07	4		1	0
Aero	0.75	+ 0.05	9		6	0
		- 0.02	4		5	0
		- 0.07	4		3	
Aero	1.00	+ 0.05	9		4	0
		- 0.02	4		3	0
		- 0.07	4		3	0

TABLE A11

START-UP AND SHUT-DOWN PERFORMANCE

Start Up: Anthes Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	No Slip Clutch		Slip Clutch	
			Smoke Number	Peak CO %	Smoke Number	Peak CO
Beckett 3450-rpm Motor	0.5	+ 0.05	2	.2	5	0
		- 0.02	2	.05	2	0
		- 0.07	2	.05	2	0
Beckett	0.75	+ 0.05	7	.3	4	0
		- 0.02	4	.05	1	0
		- 0.07	4	.05	1	0
Beckett	1.00	+ 0.05	9	.3	5	0.3
		- 0.02	5	.05	8	0
		- 0.07	5	.05	6	0
Aero 3450-rpm Motor	0.50	+ 0.05	> 9	.015		
		- 0.02	9	.015		
		0.07	9	.015	2	0
Aero	0.75	+ 0.05	> 9	0.02		0
		- 0.02	9	0.018	5	0
		- 0.07	8	0.022	8	0
Aero	1.00	+ 0.05	> 8	0.025	8	0
		- 0.02	9	0.015	6	0
		- 0.07	9	0.015	6	0

TABLE A12

START-UP AND SHUT-DOWN PERFORMANCE

Shut-Down: Anthes Furnace

Burner	Nozzle US gph	Nominal Draft Inch wg	No Slip Clutch		Slip Clutch	
			Smoke Number	Peak CO %	Smoke Number	Peak CO %
Beckett 3450-rpm Motor	0.5	+ 0.05	2		2	0
		- 0.02	6		0	0
		- 0.07	1			
Beckett	0.75	+ 0.05	9		4	0
		- 0.02	9		1	0
		- 0.07	7		1	0
Beckett	1.00	+ 0.05	9		8	0
		- 0.02	5		2	0
		- 0.07	5		2	0
Aero 3450-rpm Motor	0.5	+ 0.05	8	0.015	6	0
		- 0.02	9	-	4	0
		- 0.07	1	-	1	0
Aero	0.75	+ 0.05	9	0.08	5	0
		- 0.02	9	0.035	2/3	0
		- 0.07	9	-	2	0
Aero	1.00	+ 0.05	9	0.04	6	0
		- 0.02	9	0.07	3	0
		- 0.07	9	0.02	3	0

TABLE A13

STEADY-RUNNING PERFORMANCE

Noise Measurements

Noise Measurements on the Grimsby Furnace: Variation With Furnace Draft

Burner	Nozzle US gph	Nominal Draft Inch wg	dbA	Octave Bands S.P.L. in dB Centre Frequency (Hz)									
				31.5	63	125	250	500	1000	2000	4000	8000	16000
Beckett	0.50	+ 0.05	67	67	68	65	72	65.5	60.5	56	52	48	45
		- 0.02	67.5	67.5	70	66.5	72.5	66	60.5	56	51.5	48.5	45.5
		- 0.07	67	68	68.5	64.5	72	65.5	60.5	55.5	51.5	48.5	47.5
	0.75	+ 0.05	69	-	72	68.5	74	65.5	62.0	57	53	52	49
		- 0.02	69	68	73	66.5	73	65.5	61.5	58	53	51.5	49
		- 0.07	68.5	69	70	65	72.5	64	62	57	53	52.5	47
	1.00	+ 0.05	69	64	68	64	72	66	59	53	50	49	44.5
		- 0.02	69	66	70	66	72	66	58	54	50	49.5	45
		- 0.07	69.5	64	68.5	66	72.5	66	57	53	50	49	45

TABLE A14

STEADY-RUNNING PERFORMANCE

Noise Measurements at Standard Draft Condition

Furnace	Burner	Nozzle	dbA	Octave Bands S.P.L. in dB Centre Frequency (Hz)									
				31.5	63	125	250	500	1000	2000	4000	8000	16000
Grimsby	Beckett	0.5	67.5 (68)	67.5	70	66.5	72.5	66	60.5	56	51.5	48.5	45.5
		0.75	69 (68.4)	68	73	66.5	73	65.5	61.5	58	53	51.5	59
		1.00	69 (69)	66	70	66	72	66	58	54	50	49.5	45
	Aero	0.5	72 (72)	71	75	68	73	71	67	64	61	57	57
		0.75		-	-	-	-	-	-	-	-	-	-
		1.00	72 (71)	72.5	75	72.5	72.5	70	67	62.5	59	56.5	55.5
Anthes	Beckett	0.5	69 (69)	77	72	66	71	64	61	56	52	51	47
		0.75		-	-	-	-	-	-	-	-	-	-
		1.00	68 (69	70	71	70	70	65	61.5	54.5	51	49.5	44
	Aero	0.5	71 (70)	74	69	70.5	74	70	67.5	64.5	59.5	56	53
		0.75	72 (72)	77	71	73	73	70	67	62.5	59.5	56.5	53.5
		1.00	71 (71)	73	66	73	70	70	66	62	58.5	55	53